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CHOICE FOR SIGNALED OVER UNSIGNALED SHOCK AS A FUNCTION OF SIGNAL LENGTH

BRUCE ABBOTT AND PIETRO BADIA

BOWLING GREEN STATE UNIVERSITY

Subjects chose between signaled and unsignaled shock conditions while signal length was varied between .5 and 2.0 seconds in steps of .5 seconds in both ascending and descending series. Preference for the signaled condition failed to develop initially for five of six subjects when signals were .5 or 1.0 seconds but became strong for all subjects when signals were 2.0 seconds (ascending series). Preference declined when signals were shortened, but for most subjects this decline was small (descending series). Since discriminable shock-free periods were present in the signaled condition at all signal lengths, these results suggest that safety may not be a sufficient condition for preference to develop for signaled shock.
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Although subjects reliably and strongly prefer signaled over unsignaled shock conditions (e.g., Badia, Culbertson, & Lewis, 1971; Lockard, 1963; Perkins, Levis, & Seymann, 1963), why they do so remains a subject of theoretical debate. According to the preparation hypothesis (Perkins, 1955, 1968), signals preceding shock allow subjects to make preparatory responses which lower the aversiveness of the shock. The signaled condition is said to be chosen because the shocks delivered within it are thus less aversive than the shocks delivered within the unsignaled condition, for which preparatory responses cannot be made. It is the signal, therefore, that is important according to a preparation view. In contrast, the safety analysis (e.g., Badia, Culbertson, & Lewis, 1971; Mowrer, 1960; Seligman, Maier, & Solomon, 1971) contends that it is the absence of the signal that is important. When a signal reliably precedes shock, the absence of the signal reliably identifies a shock-free, or safe, period. In the unsignaled condition, where such cues are not available, shock-free periods cannot be discriminated from shock periods, and the entire condition may take on the characteristics of a shock period. According to the safety view, subjects choose the signaled condition in order to obtain discriminable periods of safety, which otherwise would not occur.

Although both hypotheses correctly predict that subjects will prefer the signaled condition, emphasis on signal properties by the preparation view and on properties of signal absence by the safety view lead to different expectations about which variables will control preference. One variable for which expectations differ under the two views is signal length. According to the safety analysis, signal length should not affect preference for the signaled condition, given that shock and shock-free periods remain discriminable and that the time spent in safety is not greatly shortened; under these conditions safety remains essentially constant. According to the preparation view, however, signal length should affect preference strongly. Longer signal durations provide more time to prepare for shock and therefore should lead, within limits, to more effective preparation. In contrast, very short signal lengths should provide insufficient preparation time and lead to a collapse of preference for the signaled condition.

Previous research investigating the effect of signal length on preference for signaled shock (Perkins, Seymann, Levis, & Spencer, 1966, Experiment 2) supports the preparation view. Perkins et al. assessed signal lengths of .5, 3,

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and 18 sec in a between-groups, shuttlebox design and found the functional relationship predicted by the preparation view; only the 18-sec group developed a reliable preference for the signaled condition. However, findings of studies investigating other parameters of the signaled shock situation have favored the safety explanation (for a recent critical review, see Badia, Harsh, and Abbott, 1979). Particularly damaging to the preparation view has been a series of experiments by Badia and his coworkers using the "changeover" choice procedure (e.g., Badia, Coker, & Harsh, 1973; Badia & Culbertson, 1972; Badia, Culbertson, & Harsh, 1973; Badia, Harsh, Coker, & Abbott, 1976; Harsh & Badia, 1975, 1976). These studies show that preference for the signaled condition is controlled by factors related to safety and not by those related to the signal.

For example, responding in extinction is supported by production of the stimulus correlated with safety but not by production of the signal correlated with shock (Badia, Culbertson, & Lewis, 1971; Badia & Culbertson, 1972); lowering the dependability of the stimulus identifying safety reduces preference but lowering the dependability of the stimulus identifying shock does not (Badia, Harsh, Coker, & Abbott, 1976); preference decreases with increasing intershock intervals (Harsh & Badia, 1976), a finding not expected by preparation theory since longer ISIs reduce the frequency of opportunities to prepare; and preference is maintained when shock in the signaled condition is increased to up to three times the intensity, four times the density, or nine times the duration of shock in the unsignaled condition (Badia, Coker, & Harsh, 1973; Badia, Culbertson, & Harsh, 1973). It does not seem likely that preparatory responses of the degree of effectiveness required to explain these latter data will be found.

In the context of these findings, the results of Perkins et al. seem out of place. However, numerous methodological differences exist between the study reported by Perkins et al. and those by Badia and his associates. These include method (shuttlebox versus operant chamber), design (between groups versus within subjects), and shock delivery system (unscrambled versus scrambled). Perhaps these methodological differences account for the differing support these data lend to the preparation and safety views. For example, Perkins et al.'s use of unscrambled shock may have favored results consistent wtih the preparation views by permitting the development of skeletal preparatory responses. Confidence in the generality of the relationship between signal length and preference would be enhanced if signal length effects could be demonstrated within subjects using the changeover method and scrambled shock.

The present study pursued three objectives. The first objective was to determine whether the functional relationship between signal length and preference for signaled shock reported by Perkins et al. can be observed using the choice paradigm employed by Badia and his associates (i.e., changeover procedure and scrambled shock). The second objective was to compare results obtained within subjects to those obtained between subjects using the same method (changeover). Grice (1966) noted that the within and between subject approaches may lead to different outcomes; whether they do is, therefore, an important question. The third objective was to examine in greater detail than heretofore the effects of signal lengths in the very short range (.5 sec to 2.0 sec).[1] It is in this range that effects of inadequate preparation time, if any, should be most pronounced.

The present study assessed preference for signaled or unsignaled shock at signal lengths of .5, 1.0, 1.5, and 2.0 sec within subjects and at lengths of 1.0 and 2.0 sec between subjects, using the changeover choice procedure and scrambled shock. Parameters other than signal length were set at values similar to those used in previous studies (e.g., Badia & Culbertson, 1972) to facilitate cross-experimental comparison.

METHOD

Subjects

Eighteen female Sprague-Dawley rats (Holtzman Company), 90 to 120 days old at the start of the experiment, were maintained on ad lib food and water in a temperature- and humidity-controlled colony room having a reversed 12-hr light-dark cycle.

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[1]Asymptotic preference values were obtained at the 2-sec signal length; therefore, plans to use longer values were abandoned.

Apparatus

All subjects were tested in a two-lever Foringer operant conditioning chamber (36.8 cm long by 25.4 cm wide by 12.7 cm high), modified so that the grid bars were perpendicular to the lever-bearing wall. The chamber was housed in a sound-attenuating box. A fan provided ventilation and a 78-dB masking noise. A houselight covered by a 2.54-cm white jeweled lens and mounted over the left lever provided the correlated stimulus, and a cue light covered by a 1.3-cm white jeweled lens and mounted over the right lever identified the termination of a session. A Sonalert supplied the tone signals.

A Lehigh Valley high-voltage AC shocker-scrambler (model 1311) delivered scrambled shock (.5 sec, 1 mA) through a 1.36-megohm resistor to the grid floor, metal walls, and levers of the chamber. Current flow was calibrated by inserting a 50K-ohm load resistor across the shocker outputs prior to the scrambler. The mechanical scrambler delivered .025 sec pulses at a rate of 6 pulses/sec. Twelve .64-cm stainless steel rods spaced 1.91 cm apart, center-to-center, formed the grid floor.

Procedure

Baseline. Subjects received 6-hr sessions on alternating days. During baseline phases, subjects were exposed to the signaled and unsignaled shock conditions (3-hr blocks, signaled condition first). In either condition, shocks were delivered on a variable-time 120-sec constant probability schedule (Fleshler & Hoffman, 1962) modified for an 8-sec minimum intershock interval. Light and darkness served as the correlated stimuli identifying the signaled and unsignaled conditions; these were counterbalanced across subjects. In the signaled condition, each shock was preceded immediately by a 1400-Hz, 88-dB tone (10 dB above background). Signal length was varied parametrically as described below. No signals occurred in the unsignaled condition.

Responses on the levers during baseline phases had no programmed consequences, but the time that would have been spent in the signaled condition had these responses been effective was recorded. This "changeover time" served as a baseline. Subjects remained in each baseline phase for a minimum of three 6-hr sessions and until changeover time stabilized within 10% across three consecutive sessions.

Changeover. Preference was assessed during the changeover phases. Signal length in changeover was always the same as in the immediately preceding baseline phase. Subjects were placed in the unsignaled condition and given the option to change to the signaled condition. A single response on either lever produced the signaled condition, together with its correlated stimulus, for a 1-min period. During this period, further responses had no programmed consequences. At the end of the period, the unsignaled condition resumed and remained in effect until the next changeover response occurred. To minimize the effect of shock-elicited responding on the changeover levers, responses on the levers during shock, and for 2.0 sec following shock, did not produce the signaled condition. Subjects remained in each changeover phase until the time spent in the signaled condition stabilized within 10% across three consecutive sessions.

Within-subjects manipulation. Six subjects were trained (baseline phase) and tested (changeover phase) at signal lengths of .5 sec, 1.0 sec, 1.5 sec, and 2.0 sec in both ascending and descending series. The signal length in

Table 1

Order of conditions and number of sessions in each condition for subjects receiving all signal lengths.

Signal length	*Condition*	*Subjects* SS-2	SS-6	SS-8	SS-10	SS-14	SS-16
.5	Baseline	5	5	4	4	7	3
	Changeover	3	6	3	3	3	4
	Baseline	13	6	3	13	5	3
	Changeover	7	3	3	13	3	4
1.0	Baseline	7	15	18	10	3	3
	Changeover	3	8	4	3	4	5
	Baseline	3	5	3	5	3	3
	Changeover	12	3	3	9	6	3
1.5	Baseline	4	3	3	3	4	3
	Changeover	3	3	4	3	3	13
	Baseline	3	3	3	3	7	3
	Changeover	5	3	3	3	4	7
2.0	Baseline	3	3	3	5	4	3
	Changeover	5	3	5	3	3	7
	Baseline	10	3	3	3	3	4
	Changeover	3	3	3	5	7	3
1.5	Baseline	3	3	5	5	4	3
	Changeover	5	3	3	3	5	3
1.0	Baseline	3	3	3	3	3	3
	Changeover	7	3	3	3	7	3
.5	Baseline	3	3	4	3	3	3
	Changeover	3	4	3	5	3	4
2.0	Baseline	3	3	3	3	3	3
	Changeover	9	3	4	3	4	5

changeover was always identical to the signal length received in the immediately preceding baseline phase. Table 1 presents the order of conditions and the number of sessions spent in each condition by each subject of the within subject manipulation.

Between-subject manipulation. Twelve additional subjects were each trained (baseline phase) and tested (changeover phase) at only one signal length. Baseline and changeover phases were followed immediately by a second exposure at the same signal length to baseline and changeover phases (replication). Six subjects received a 1.0-sec signal, the others a 2.0-sec signal. Table 2 indicates the order of conditions and number of sessions spent in each condition by subjects of the between subject manipulation.

RESULTS

Figure 1 displays the results of the within subject manipulation. Redeterminations of points within the ascending series generally fell close to original values; for clarity, these values therefore have been pooled in the figure. During baseline phases (squares), changeover responses activated the changeover timer for 1-min periods but did not produce the signaled condition. Under these conditions, the percentage of session time cumulated on the changeover timer (percent time in changeover) by each subject remained at baseline levels under all signal lengths. During changeover phases (circles), each changeover response produced 1 min in the signaled condition; under these conditions, the percent time spent in changeover varied depending on the length of the signal. When signal length was .5 sec, five of the six subjects responded at or near baseline levels, demonstrating little or no preference for the signaled condition. With increasing signal length, both the number of subjects showing a preference and the strength of preference increased, with most subjects displaying asymptotic levels of changeover responding at the 2.0-sec signal length. When signals were then shortened (descending series), changeover responding declined. However, responding tended to remain stronger at each signal length than was the case for corresponding points in the ascending series. When signal length was subsequently returned to 2.0 sec (Figure 1, final points), changeover responding for all but one subject (SS-14) returned to levels previously observed under this condition.

Only one subject (SS-6) displayed a strong preference for the signaled condition on first exposure to the .5-sec signal length. This strong preference continued as the signal was lengthened. A moderate decline in changeover occurred, however, when the signal was subsequently shortened.

Figure 2 shows the mean percent time spent in the signaled condition during the baseline and training conditions by individual subjects in the two groups of the between subjects analysis. The trend shown in the within-subjects analysis appears also in these data: while every subject in the 2.0-sec group spent more than 70% of the session in the signaled condition (upper figures), only one subject (SS-56) in the 1.0-sec group spent greater than 50% (lower figures), and three of the six remained at baseline levels.

Table 2

Order of conditions and number of sessions in each condition for subjects receiving only one signal length.

Signal length	*Condition*	*Subjects*					
		SS-42	*SS-48*	*SS-52*	*SS-32*	*SS-56*	*SS-62*
1.0	Baseline	3	3	3	3	3	3
	Changeover	4	3	4	3	11	8
	Baseline	10	3	3	3	3	3
	Changeover	3	3	4	3	6	3
		SS-38	*SS-40*	*SS-44*	*SS-50*	*SS-60*	*SS-64*
2.0	Baseline	3	6	4	3	8	3
	Changeover	5	11	7	8	4	4
	Baseline	4	3	4	3	3	5
	Changeover	3	3	5	3	4	3

DISCUSSION

The major finding of this study is that preference for signaled shock increases as a function of signal length over a range of .5 to 2.0 sec. Similar functions were obtained for individual subjects receiving all signal lengths (Figure 1) and for different groups of subjects receiving only one signal length (Figure 2). When signal length initially was .5 sec (Figure 1), five of six subjects failed to acquire preference for the signaled condition, despite retraining at this value and a second opportunity to change to the signaled condition (ascending series). These results are particu-

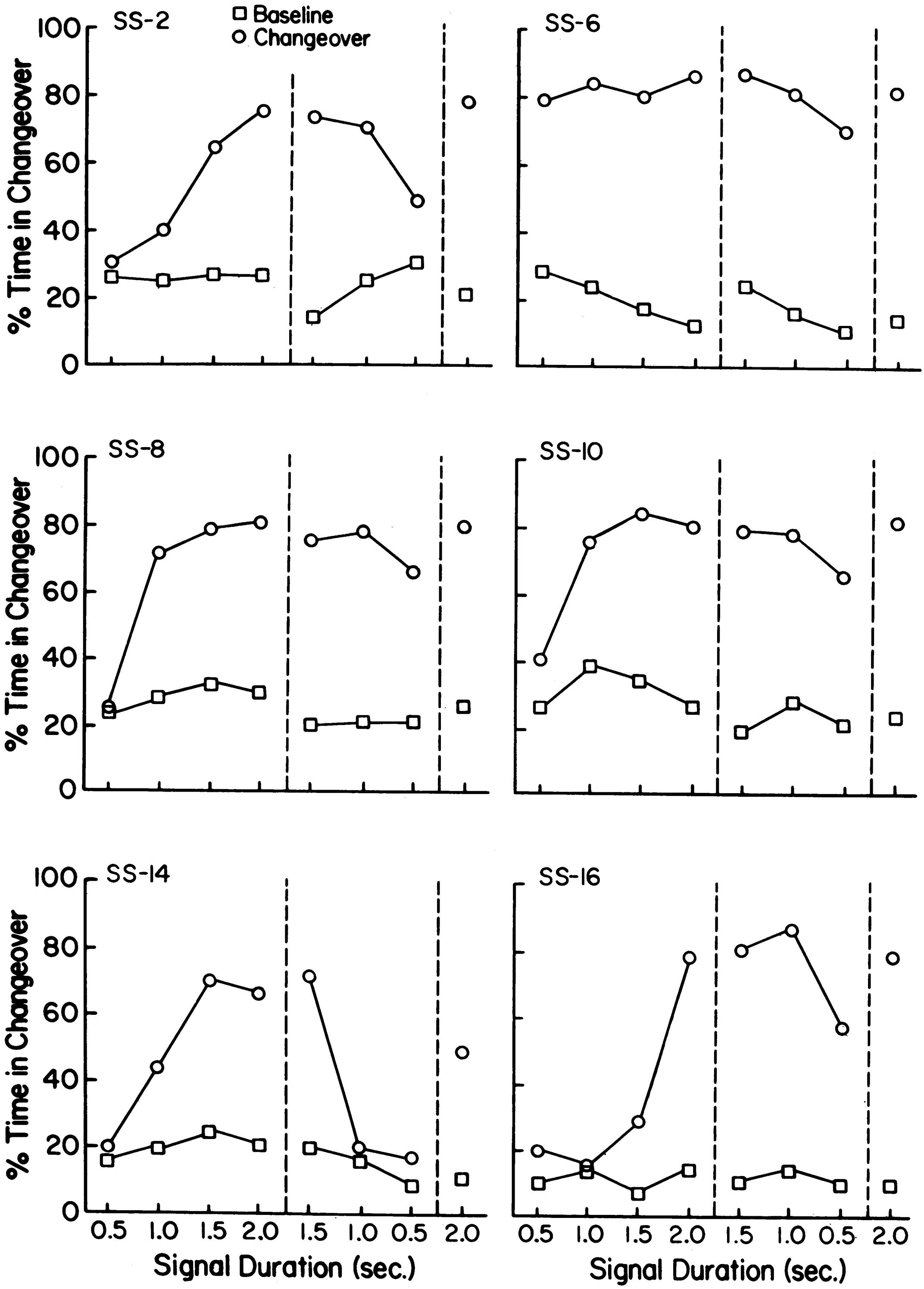

Fig. 1. Percent time in changeover as a function of signal length for within subject manipulation. Each point represents the mean for the final three sessions in each condition, pooled over replications where possible (points to left of first dotted line). Circles show responding during changeover; corresponding squares show responding in the immediately preceding baseline phase at the same signal length. Session length was 360 min.

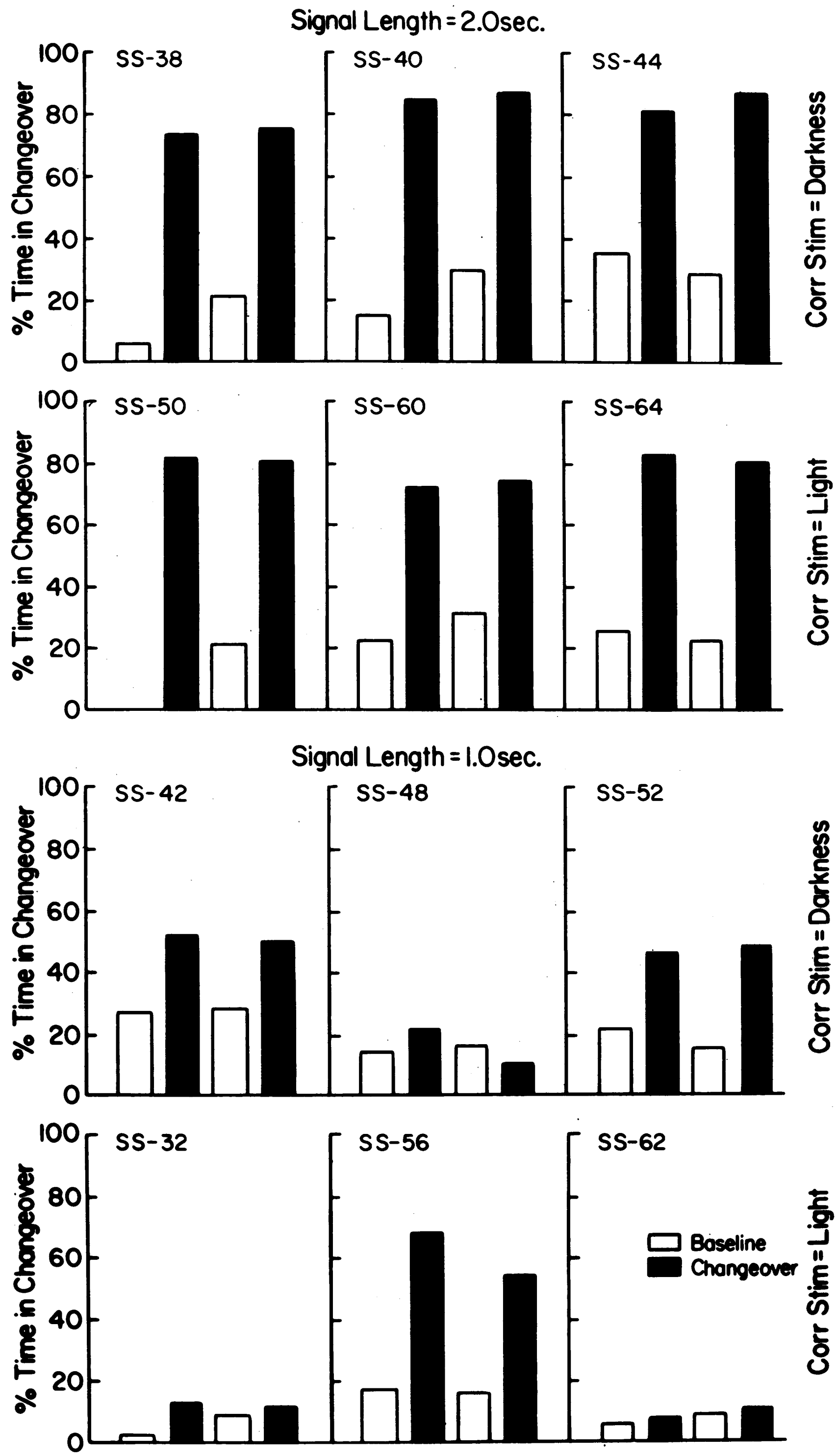

Fig. 2. Percent time in changeover as a function of signal length for between subject manipulation. Upper graphs show responding in baseline (white bars) and changeover (black bars) when signal length was 2.0 sec; lower graphs show responding at similar times when signal length was 1.0 sec. Bars represent the means of the final three sessions in each condition.

larly striking in that other parameters of this study were identical to those used in previous studies by Badia and his associates in which a strong and reliable preference for the signaled condition emerged on first exposure to the changeover contingency (e.g., Badia, Coker, & Harsh, 1973; Badia & Culbertson, 1972; Badia, Culbertson, & Harsh, 1973; Badia, Culbertson, & Lewis, 1971). As the signal was lengthened, preference increased, with strong and generally asymptotic preference levels developing at or before the 2.0-sec length.

When signals were shortened (descending series), all subjects showed declines in changeover responding, although for most the decrease was moderate. Recapturing of stronger levels on the final return to the 2.0-sec length shows that signal length was the factor responsible for this decline and not some time-dependent process such as habituation to shock. However, maintenance of responding under the .5-sec signal condition at levels considerably above baseline following exposure to longer signals presents some problems for analysis. One possible explanation is that discrimination of shock and shock-free periods was difficult under the .5 sec condition and resulted in the initial failure by five of six subjects to acquire preference for the signaled condition. In this view subsequent exposure to an "easy" discrimination task at longer signal durations aided the discrimination. When subjects were then exposed to shorter durations, the discrimination, although still difficult, was aided by attention to relevant stimulus dimensions (i.e., "easy-to-hard effect," cf. Lawrence, 1952).

This view could account both for the initial preference failure and the subsequent maintenance at reduced levels. There are, however, at least two reasons to reject this parsimonious and apparently reasonable view. First, there is good independent evidence that adequate stimulus control is established by discriminative stimuli shorter than .5 sec. For example, where shock presence was the discriminative stimulus, rats typically responded within .25 sec of stimulus onset (e.g., Migler, 1963). Using a short (1.2-sec) nonaversive discriminative stimulus, Blough (1972) showed that pigeons typically would respond within .25 to .45 sec. In these situations, subjects must both discriminate the presence of the stimulus and react appropriately; thus the discrimination process must operate within considerably less time than .25 sec. A second argument relates to the data reported by Perkins et al. (1966). In their study, preference was strongest at 18-sec signal lengths. The present study does not rule out the possibility that 18-sec signals will produce even stronger preferences than 2.0-sec signals, although the "ceiling" appeared to have been reached within the current methodology. Since discrimination is adequate at 2.0 sec, the discrimination hypothesis cannot deal with these results. An alternative explanation for the failure to recapture baseline levels at short signal lengths is that preferences conditioned under longer signals were not given sufficient time to extinguish under the shorter conditions. Earlier work in a similar situation (Badia & Culbertson, 1972) showed that subjects would maintain relatively strong responding for extended periods following acquisition when the signal was entirely *removed* (their EXT II condition). Obviously the conditioned discrimination of shock and shock-free periods could not have been a factor under these conditions. To explain maintenance of responding in EXT II, Badia and Culbertson (1972) noted that responding under this condition continued to produce the stimulus previously correlated with safety, which retarded extinction of responding. The descending-series data of the present study are consistent with this analysis.

In general, the present results confirm those of Perkins et al. (1966) despite significant differences in methodology. A major difference in results between these studies is the duration at which a strong preference for the signaled condition first appeared. As noted previously, Perkins et al. used signal durations of .5, 3.0, and 18.0 sec. While the present study obtained strong preference for all subjects when signal length was 2.0 sec, Perkins et al. obtained strong preference only at the 18-sec length. Preference at 3 sec was in the expected direction but failed to differ significantly from chance. However, a previous study using methodology similar to that of Perkins et al. (1966) and 3-sec signals obtained strong preferences for the signaled condition (Perkins, Levis, & Seymann, 1963). The present results are consistent with these earlier findings and with numerous findings obtained using the changeover procedure in which strong preferences emerged using a 5-sec signal length (e.g., Badia & Culbertson, 1972).

With regard to theoretical implications, the present results clearly favor the preparation hypothesis while raising serious questions about the adequacy of the safety analysis. The preparation view easily accounts for the increased preference at longer signal durations simply by making the reasonable assumption that longer signals allow more effective preparation. In contrast, the safety analysis cannot account for these data, for despite changes in signal duration across conditions, discriminable shock-free periods were present throughout. If safety were the only factor determining preference for the signaled condition, then strong preferences should have developed in the initial test at the .5-sec signal length. Yet preference failed to develop in four of five subjects tested under this condition. It follows that discriminable shock-free periods cannot be a sufficient condition for preference.

These implications, clear as they may be in the present context, contrast sharply with implications of other research on preference for signaled shock. Other research strongly favors a safety analysis while providing very little support for preparation (e.g., Arabian & Desiderato, 1975; Badia & Culbertson, 1972; Badia, Coker, & Harsh, 1973; Badia, Harsh, Coker, & Abbott, 1976; Harsh & Badia, 1975). These other studies indicate strongly that the presence of discriminable shock-free periods within the signaled condition is an important determinant of preference. If, as the present findings suggest, safety is not a sufficient condition for preference, these latter findings suggest that safety is at least a necessary condition (Badia, Harsh, & Abbott, 1979).

Apparently the situation is more complex than either the preparation or safety analyses suggest. It is possible that both preparatory responding and safety may be important. The present data may be assimilated with previous research if it is assumed that safety is of value if, and only if, sufficient preparatory time occurs following termination of the safe stimulus. Given that sufficient time to prepare is available, then parameters of safety may control preference responding. This view, which emphasizes both stimulus control of preparatory responding by the signal and the reinforcing properties of safe periods, could explain both the control over preference exerted here by signal length and the control shown in previous studies by factors related to safety (e.g., Badia & Culbertson, 1972; Badia, Harsh, Coker, & Abbott, 1976; Harsh & Badia, 1975, 1976; Safarjan & D'Amato, 1978).

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